

## THE BIOLOGY OF A GEOTHERMALLY HEATED BRACKISH WATER POOL AT POHOIKI, HAWAI'I

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### INTRODUCTION

A substantial number of myxohaline (brackish water) ponds can be found on the Island of Hawai'i along the Kona coast and in the Kapoho-Pohoiki area of Ka'u. The brackish water is a result of subterranean freshwater mixing with intruding seawater. Typically the water level in these ponds fluctuates with the tide. A unique aspect of these ponds is that many are without visible surface connection to the sea; the term anchialine has been proposed by Holthuis (1973) to describe these unique coastal ponds. A faunal survey of Hawai'i Island anchialine ponds conducted by Maciolek and Brock (1974) revealed a biota characteristic of these ponds. Animal species occurring most frequently included two small endemic shrimps, Halocaridina rubra (Holthuis) and Metabetaeus lohena (Banner). A gastropod, Melania sp., and an unidentified amphipod were also relatively abundant. Algal communities were found in all ponds and were quite varied. Encrusting minute algae such as Shizothrix, Chroococcus, and Gloeocapsa were characteristic of the anchialine ponds.

A pond adjacent to Isaac Hale Beach Park was chosen for our present study (Fig. 1). This particular anchialine pond is unique in several aspects. In contrast to ponds in the open lava fields of the Kona coast, this pond is located in a heavily shaded, wooded area. It also possesses one of the highest water temperatures of such ponds and is easily accessible.

### SCOPE AND OBJECTIVES OF STUDY

The major objective of the study was to gather basic information on the physical and biological characteristics of the pond. Emphasis was placed on studying biological parameters, in particular, the microorganisms since virtually nothing is known about the microbiology of these ponds.

Hydrographic measurements which included a determination of salinity, temperature, and dissolved oxygen were taken during each visit. Microbiological sampling included tests for total coliform bacteria, total heterotrophic bacteria, hemolytic bacteria, thermophilic bacteria, fungi, and yeast. Additional

microbiota were determined from microscopic examination of the bottom sediment and growth scraped from rocks lining the pool. Larger animals, which were exclusively shrimp, were caught with hand nets.

## MATERIAL AND METHODS

Salinity and temperature measurements were taken with a Yellow Spring Instrument (YSI) Model 33 Salinometer with thermo-probe. Dissolved oxygen concentrations were determined with a YSI Model 51A Dissolved Oxygen Meter.

The collections of surface, sub-surface, and bottom waters were made with sterile 250-ml Nalgene bottles and transported back to the laboratory for analysis. Heterotrophic bacteria were enumerated by plating appropriate dilutions of water onto nutrient agar and saline nutrient agar plates (nutrient agar plus 2.5% sodium chloride) and incubating the plates at 35°C. Total coliform bacteria numbers were determined by filtering the water samples through Gelman GN-6 membrane filters (0.45  $\mu$ m pore size) followed by incubation on MF-Endo Medium at 35°C. Hemolytic bacteria were enumerated by plating the water samples onto 5% sheep blood agar and observing the clearing of blood after incubation at 35°C for 48 hours; the hemolytic activity is characteristic of a number of human pathogenic bacteria. Sabouraud agar supplemented with 2.5% sodium chloride was used to enumerate the fungi and yeast present in the pond water. Difcoagar media were for all enumerations.

Sediments used for the study of microinvertebrates were obtained with a fine mesh hand net, while the encrusting growth on rocks was collected by scraping. All sediments and encrustations were initially examined with a Nikon SMZ dissecting microscope at 10X magnification. Examinations at higher magnification were with wet mounts using a Zeiss phase-contrast microscope.

The macrofauna, which consisted solely of the two endemic shrimp, were captured with a fine mesh net. All specimens were brought back alive to the laboratory and maintained in 5-gallon all-glass aquaria. Shrimp size was measured from rostrum tip to the telson tip.

## RESULTS AND DISCUSSION

Over the several months of measurements, the surface salinity of the pond ranged from 4.7 to 7.8 ppt with a mean of 7.1 ppt. The bottom salinity measured slightly higher. The brackish nature of the pond water is no doubt related to the mixing of the ground water and the underlying seawater. The very slight daily differences in salinity may be due to the changing tide level

and/or variations in the flow of ground waters. Table 1 shows a typical set of salinity measurements, along with temperature and dissolved oxygen level.

The dissolved oxygen level on February 21, 1980, averaged about  $4.1 \pm 0.1$  ppm with no significant difference in the surface or bottom water of the pond. The concentration of oxygen is approximately 60% of saturation.

The temperature measurements showed surface waters to range between 33°C to 35°C over the period sampled (Table 2). Air temperature during this period ranged between 23°C and 28°C. The water temperature, usually taken during the late morning, was generally 8° to 10°C higher than the air temperature. Even greater differences might be expected during the night and early morning hours.

The water level in the pond rises and falls a maximum of 0.3 m with the tide. Styrofoam chips broadcasted and submerged throughout the pond showed no detectable lateral water movement other than surface movement due to wind. Dye tests were considered but not conducted because the pond is used for bathing and swimming.

The macrobiota of the pond is represented exclusively by two small endemic crustaceans, the alpheid shrimp, Metabetaeus lohena, and the caridean shrimp, Halocaridina rubra ('ōpae'ula). Macrophytes are absent. The Halocaridina are active and are usually seen feeding with their chelipeds picking at the rock surface. Examination of the ingested materials in their gut revealed primarily bacteria, diatoms, filamentous algae, plant detritus, and possibly protozoa. Descriptions of the feeding habits by Banner and Banner (1960), and Wong (1975) indicate Halocaridina to be a microphagous herbivore. The Metabetaeus, in turn, is believed to utilize the smaller carideans as a food source. This predator-prey relationship was first noted by Banner and Banner (1960). Our field observations show the alpheid shrimp to be an active predator. The Metabetaeus can be seen foraging in the open or waiting in the shaded crevices for its potential prey to pass. However, Halocaridina maintains an "escape posture" in which the abdomen is fully extended while it is walking, at rest, or even during feeding. With a rapid flex of its abdomen the Halocaridina rapidly darts upward and escapes. We have witnessed several captures of Halocaridina by Metabetaeus during daylight hours in the field. When populations of these two shrimps are confined in a small aquarium, a gradual decrease in the numbers of Halocaridina was observed. Metabetaeus will also feed on smaller members of their own kind in preference to Halocaridina, when the two species were of similar size.

Although Metabetaeus is a predator of Halocaridina, the caridean shrimp is probably not the sole food source. We have maintained Metabetaeus in aquaria of various sizes in the absence of Halocaridina for several months and have observed cannibalism of smaller individuals. Also, microscopic examination of gut contents of specimens captured in the pond showed the presence

of very small mineral particles, bacteria and diatoms, and the absence of cuticular matter. These observations suggest that Metabetaeus utilizes detrital material in addition to Halocaridina. Indeed, it seems likely that smaller specimens of Metabetaeus utilize detrital materials exclusively.

The population of the two shrimps in the pool, which measures roughly 7.5 m by 4.5 m with a 1 m depth, is roughly estimated at about 10,000 to 20,000 animals. Accurate determination of the population is difficult since the distribution of animals is extremely heterogeneous. During daylight hours, relatively few shrimp are found on the pool bottom and in the water column. Most of the shrimp are found in the rock rubble and in the dark rock overhangs along the side of the pool.

While both shrimps are red in color and resemble each other somewhat, size and the appearance of the chela can be used as distinguishing characteristics. As shown in Figure 2, the Metabetaeus are clearly larger than the Halocaridina with some size overlap. The largest Metabetaeus in the pond eluded capture. Halocaridina was found in proportion to Metabetaeus at 193 to 15, a ratio of almost 13:1. It is not known whether this ratio of prey to predator is true of the pond population.

The pond sediment is made up mostly of plant foliage in various stages of decomposition and a great deal of shrimp fecal pellets. Microinvertebrates are conspicuously absent except for a few nematodes and copepods. In contrast, complex communities of unicellular procaryotic and eucaryotic forms were found. The procaryotes, represented by bacteria and blue-green algae, are particularly abundant. Heterotrophic bacteria numbers as determined by spread plating methods averaged 862 per ml of surface water (Table 3). Their numbers averaged 650 per ml in pond bottom water. Bacteria concentrations were far higher in the sediment, however, where the count averaged 31,500 per ml of sediment slurry. The bacterial counts we obtained for the pond water and sediments are of a magnitude or two lower than those reported by Wetzel (1975) for oligotrophic lakes. We feel the enumeration methods currently employed by us grossly underestimates the indigenous bacteria population, perhaps by a factor of 100 times. Since the bacteria are an extremely heterogeneous group, the use of any single medium is likely to be selective for the growth of only certain physiological types. Jannasch and Jones (1959) showed that much larger bacterial populations could be obtained when methods such as direct microscopic enumeration or microcolony counts on membrane filter were used. These methods will be considered for future sampling.

Our tests for hemolytic bacteria showed these bacteria present in very low concentration, averaging less than 20 per ml. Bacteria, which are capable of lysing red blood cells, are common to the surface and nasal-oral microflora of man. Their persistent presence in the pond in significant numbers would be of public health interest. The bacteriological quality of water is usually determined, however, by the levels of coliform bacteria found in the water. Coliform bacteria are part of the intestinal

microflora of all animals and their presence is used as an indicator of possible pollution. Our sampling showed the total coliform count to be quite variable, ranging from a low of less than 2 to a high of 2400 per 100 ml of pond water. The average coliform count was about 260 per 100 ml. The lowest and highest counts obtained occurred on the same day approximately 3 hours apart. The high count was found in a water sample taken while the pond was occupied by seven persons, including five adults and two young children. The youngest child, wearing a diaper, had a bowel movement while in the pond. The parents, children, and friends left the pond soon after only to be replaced by a newly arrived party of three. It appears that bacteriological water quality of this pond, as measured by the coliform bacteria index, will vary with the type and degree of human activities.

Protozoa are found in abundance in the sediment and its interstitial water. These eucaryotic protists are represented by three major taxa -- Ciliata (ciliates), Mastigophora (flagellates), and Sarcodina (amoebas). Using Kudo (1963) as a reference, a total of 20 protozoan genera were found (Table 4). The ciliates were represented by 11 species. Flagellates and amoeba were represented by seven and six species, respectively. All species identification are tentative.

Most of the ciliates were bacterivorous forms. Large ciliates, such as Uroleptus sp., were seen actively moving through the sediment apparently feeding on bacteria. The ciliates are estimated at about several hundred to several thousand per ml of suspended sediment. They appear to be randomly distributed. Cairns (1974) has indicated that patchiness in protozoa types and numbers is typical of many aquatic sediments. Attempts at enumerating protozoa concentrations more precisely with a dilution extinction method were not successful. The flagellated protozoa were all minute forms represented most frequently by Bodo sp. and Monas sp. Flagellates were more abundant than the larger ciliates by a factor of 3-10. Again, accurate counts of the flagellates were not possible. The sarcodinids were represented by five amoeba species and a helizoan, Actinophrys sol (Kudo). Under the confines of a slide, a specimen of Actinophrys was observed capturing, and apparently consumed six flagellates over a period of 2 hours.

Microorganisms play an important role in the ecology of this pond. The blue-greens, Oscillatoria and Lyngbya, are primary producers (Prescott 1968). Other blue-greens include Chroococcus and Scytonema. The cyanophyte components of this pond are similar to some anchialine ponds in Maui (Wong 1975). All contribute to the overall productivity of the pond. However, the decomposition of leaf litter and other organic matter by bacteria and saprophytic fungi probably provides the major source of energy for this pond system. Degradative activities result in the production of a substantial amount of microbial biomass which is directly and indirectly utilized by the two shrimp species. We feel that the rapid production of microbial biomass resulting from the decomposition of exogenous plant materials allows the pond to support the present large shrimp population.

## SUMMARY

Our study has shown the anchialine pond at Pohoiki to possess a limited macrobiota consisting of only two species. This unique pond deserves further study. The interactions of the two endemic shrimp species need to be examined. And the role of microorganisms and their relationship to the abundant population of crustaceans needs to be clarified.

The pond is not only of scientific interest, but is presently enjoyed by the public as a scenic site and a bathing area. Current use of the pond has resulted in substantial litter, physical damage, and probably a deterioration of the water quality. Proposed expansion of the Isaac Hale Beach Park and trail developments (USDA, Soil Conservation Service 1977) would mean a greater influx of people into the pond with potentially disastrous results.

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TABLE 1. Water temperature, salinity, and dissolved oxygen levels of Pohoiki Pond, island of Hawai'i, 21 February 1980.

	Temperature* (°C)	Salinity* (ppt)	Dissolved Oxygen (ppm)
Surface	34.4 (0.27)	6.0 (0.12)	4.10
Sub-surface	34.7 (0.13)	6.1 (0.18)	4.16
Bottom	34.8 (0.06)	6.2 (0.29)	4.11

\* Mean values of 6 measurements with standard deviation in parentheses.

TABLE 2. Surface water temperatures of Pohoiki Pond, island of Hawai'i.

Date	Time	Temperature, °C	
		Surface	Air
2/14/80	1045	32.8	23
2/21/80	1105	34.4	24-26
4/04/80	1130	33.7	25
5/16/80	1030	35.0	28



TABLE 3. Microorganism concentrations in the surface water of Pohoiki Pond, island of Hawai'i.

Type of Microorganism	Viable Cell Count Per ml Water	
	Range	Mean
Heterotrophic Bacteria	470-995	862
Hemolytic Bacteria	< 1-80	< 20
Coliform Bacteria	2-2,400	260
Fungi/Yeast	40-90	70

TABLE 4. Protozoa in Pohoiki Pond sediments, island of Hawai'i.

Taxa	Genera
Ciliata	<u>Balanonema</u> sp.
	<u>Colpoda</u> sp.
	<u>Cristigera</u> sp.
	<u>Cyclidium</u> sp.
	<u>Euplotes</u> sp.
	<u>Nassula</u> sp.
	<u>Spirostomum</u> sp.
	<u>Stylonychia</u>
	<u>Uroleptus</u> sp.
	<u>Urotricha</u> sp.
Mastigophora	<u>Actinomonas</u> sp.
	<u>Bodo</u> sp. (several species)
	<u>Euglena</u> sp.
	<u>Monas</u> sp.
	<u>Ochromonas</u> sp.
	<u>Oikomonas</u> sp.
Sarcodina	<u>Rhynchomonas</u> sp.
	<u>Actinophrys</u> sp.
	<u>Amoeba</u> sp. (several species)
	<u>Naegleria</u> sp.

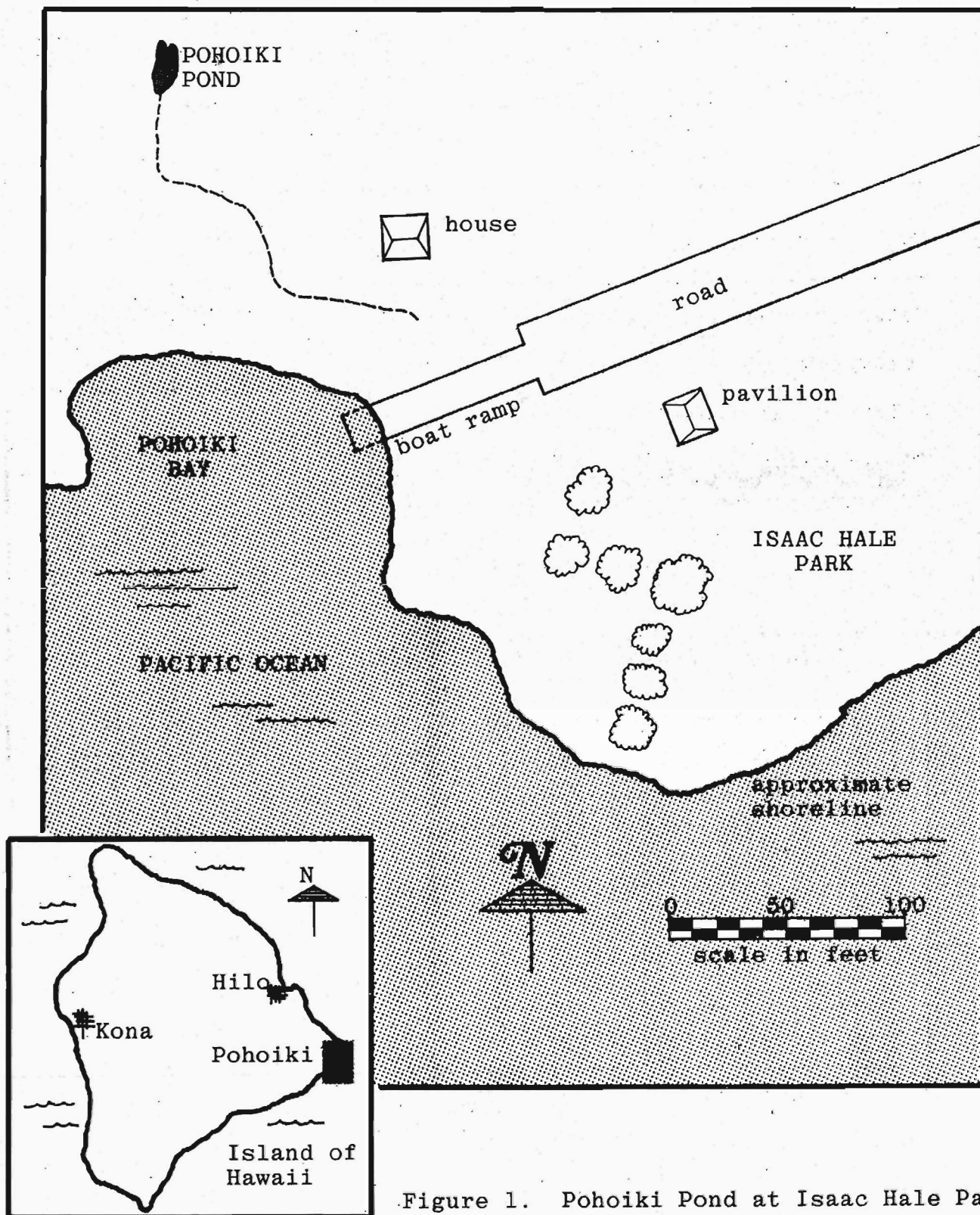


Figure 1. Pohoiki Pond at Isaac Hale Park

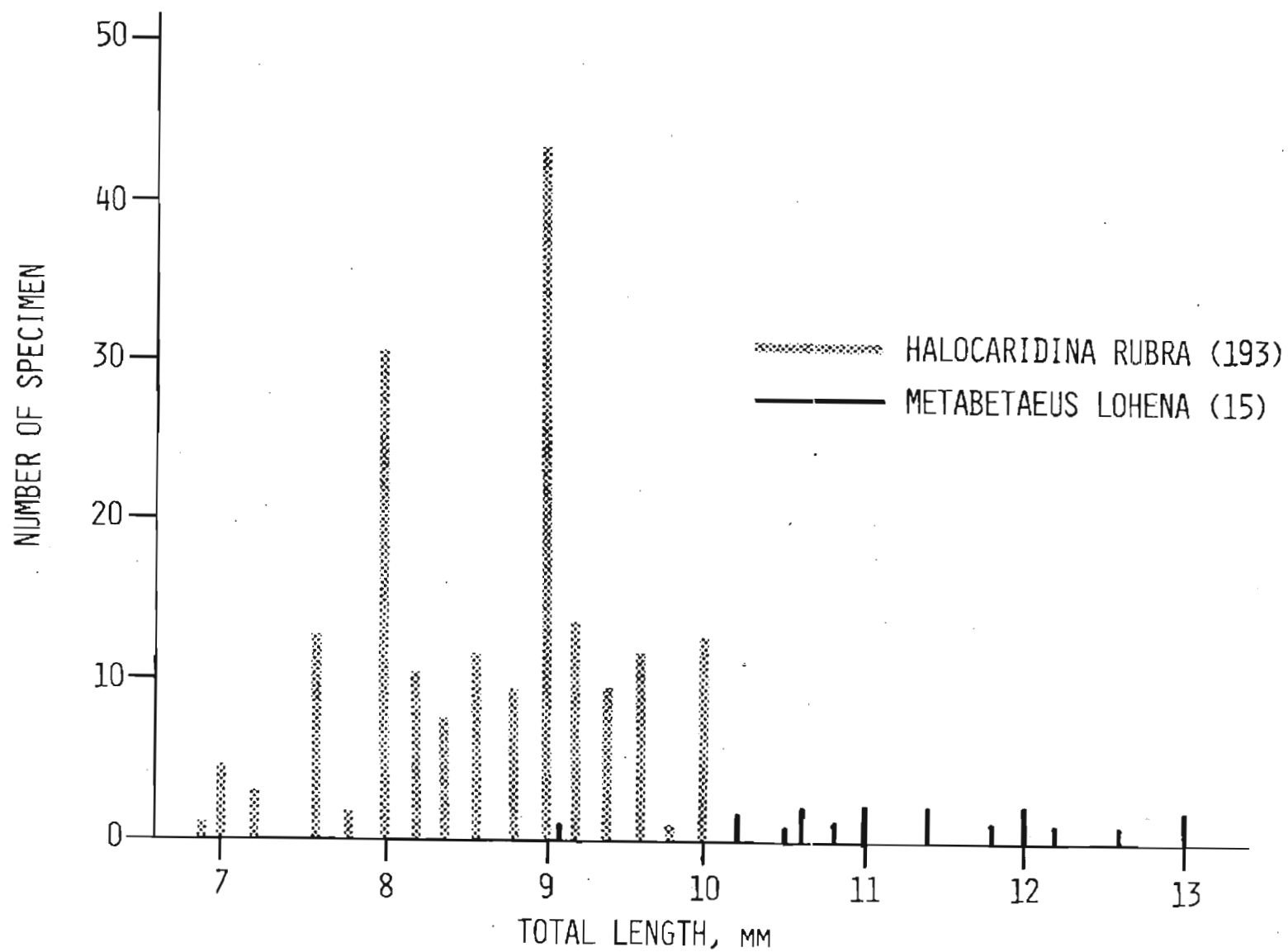


Figure 2. Size Distribution of Halocaridina rubra and Metabetaeus lohena.